

日本結晶成長学会
バルク成長分科会

第52回研究会資料集

— Si単結晶と

Si基板上ヘテロエピタキシャル成長技術—

共催： ナノ構造・エピタキシャル成長
分科会

日時： 平成14年 2 月 8 日(金)

場所： 湘南工科大学東京キャンパス

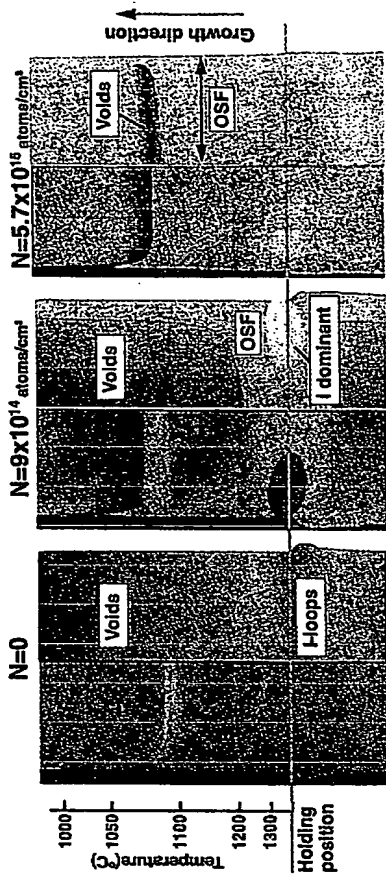
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Summary : Grown-In Defects and Oxygen Precipitation in Nitrogen-Doped CZ-Si

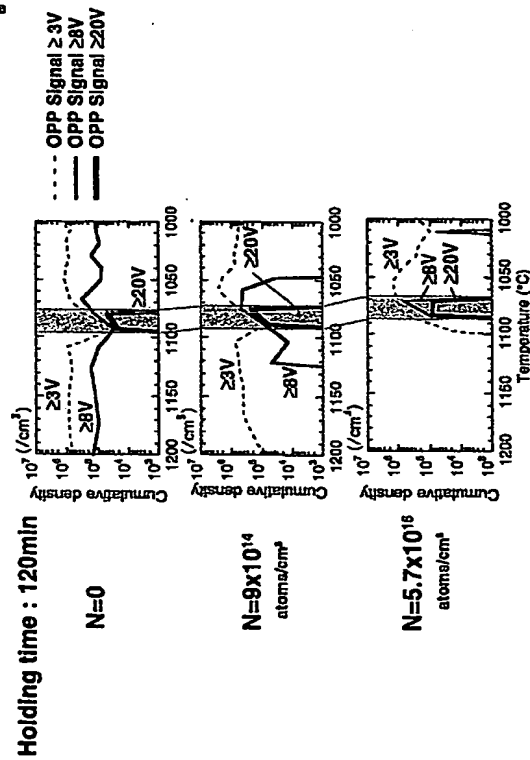
- Grown-in defects
 - Void defects
 - Size : Decrease with nitrogen concentration
 - Density : Increase with nitrogen concentration
 - Morphology : platelike triclinic
 - Grown-in oxygen precipitates
 - Density : Increase with nitrogen concentration
 - Morphology : Platelet (with strain field)
 - existence of N and O
 - Defect regions of nitrogen-doped crystals
 - V region (Voids), OSF region and I region (I-loops)
 - Determined by Nitrogen concentration and V/G
- Oxygen precipitation
 - Precipitate density keep constant level regardless of heat-treatment temperature (even in high temp $\sim 1100^\circ\text{C}$) or time ($n=3/2$ in Johnson-Mehl Equation)
 - thermally stable oxygen nuclei exist

Defect Distribution Change in Growth Held Crystals of Different N Conc.

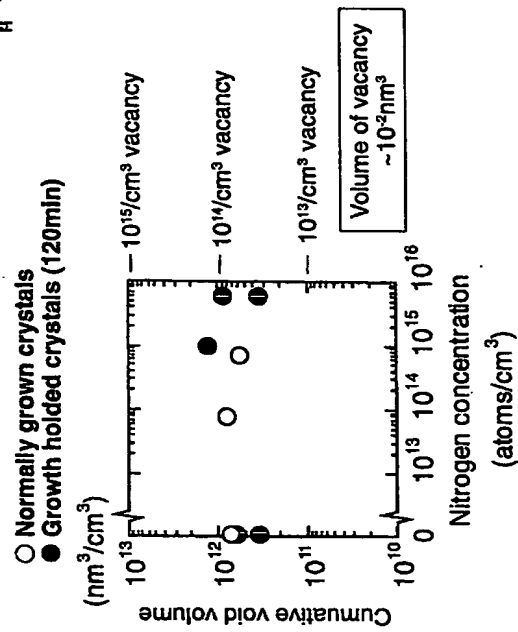
Holding time : 120min
X ray topograph : $800^\circ\text{C}4\text{hrs}+1000^\circ\text{C}16\text{hrs}$



Temperature Dependence of Cumulative Defect Density in growth held crystals of Different N Conc.

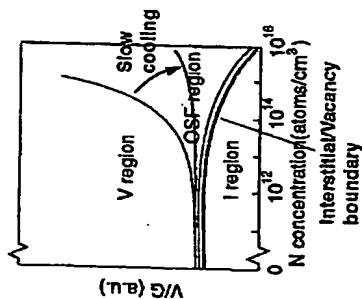


Dependence of Cumulative Void Volume on N Conc.



Summary : Growth Holding Experiments of Nitrogen-Doped CZ-Si

- Results
 - I region shrinks with increase of nitrogen
 - Voids formed even in OSF region
 - Void formation temperature becomes lower
 - Total void volume is nearly constant regardless of nitrogen concentration
- Mechanisms
 - Nitrogen suppresses the void growth
 - Residual vacancies form oxygen clusters
→thermally stable oxygen nuclei exists



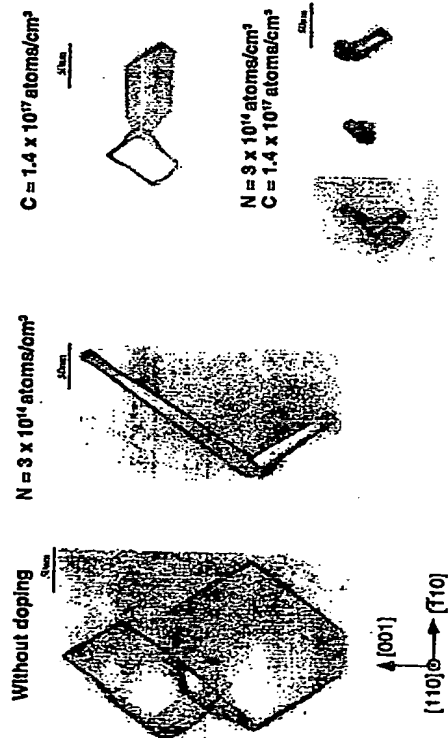
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Experimental

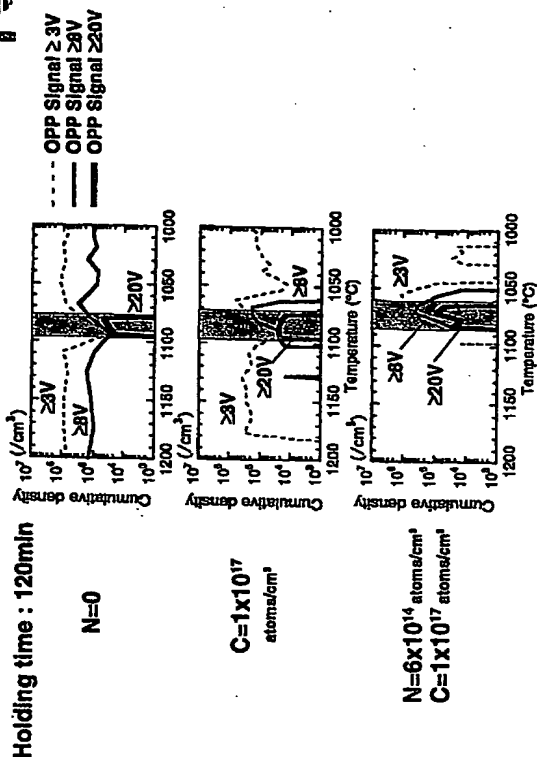
Samples
 Diameter : 150mm and 200mm
 Resistivity : 8-12 Ω cm
 Oxygen : $7-9 \times 10^{17}$ atoms/cm³ (JEIDA)
 Nitrogen : $3 \times 10^{14}-3 \times 10^{15}$ atoms/cm³
 (measured by SIMS, calculation)
 Carbon : 1×10^{17} atoms/cm³ (JEIDA)

Evaluation
 As grown
 LSTD scanner, BMD analyzer
 Optical Precipitate Profiler (OPP) : Size distribution
 TEM
 OSF evaluation
 1100°Cx1hr(wet)→Wright Etching
 Oxygen precipitation
 800°C4hr+1000°C16hr, 700~1100°C 8~128hr*
 →Reduced OI (FTIR), precipitate density (BMD analyzer)
 *before and after epi-layer growth (>1100°C)

TEM Images of Voids in N-doped, C-doped and N+C-doped Crystals

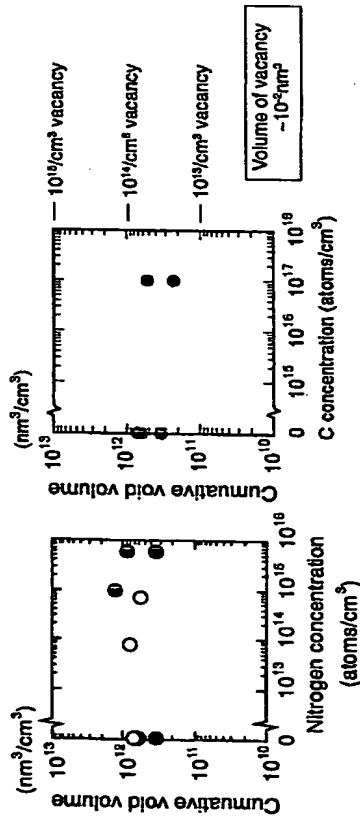


Temperature Dependence of Cumulative Defect Density in growth held crystals (C doped and N+C doped)



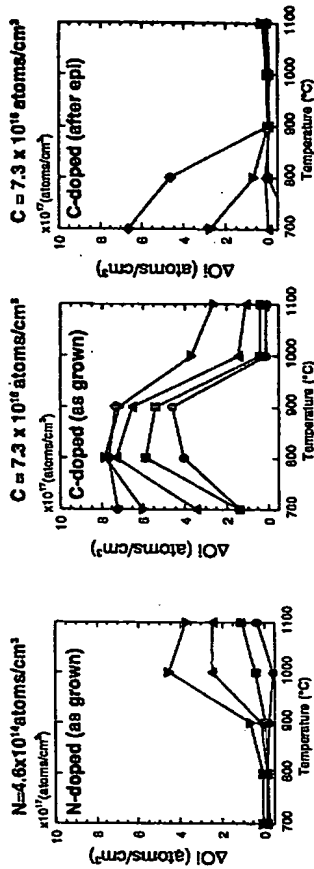
Dependence of Cumulative Void Volume on N Concentration or C Concentration

- Normally grown crystals
- Growth holded crystals (120min)



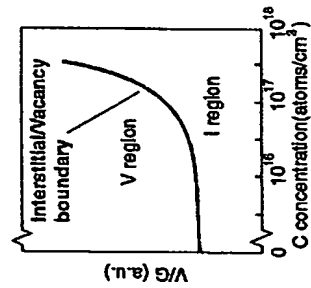
Reduced Oxygen Concentration Dependence on Heat-Treatment Temperature

Epitaxial Layer Growth : >1100°C



Summary : Growth Holding Experiments of Carbon-Doped CZ-Si

- Results
 - I region expands with increase of carbon
 - Void formation temperature becomes lower
 - Total void volume is nearly constant regardless of nitrogen concentration
- Mechanisms
 - Induced vacancy concentration becomes lower by Carbon-doping
 - Inconsistent with the result of total void volume



Summary (Nitrogen and Carbon Effects)

Grown-In Defects Formation

-Void

Same effect (density → increase, size → decrease)
→ different mechanism

N-doping → platelike or rodlike voids

-Defect Region

N-doping shrinks I-region and C-doping expands I-region

-Grown-In Oxygen Precipitation

N-doping induces stable oxygen nuclei (grown-in precipitates)
→ generate OSF region

Oxygen Precipitation enhancement

-High temperature (1000~1100°C) : N-doping (stable nuclei)
-Low temperature (<800°C) : C-doping (nucleation by C)